Journal Watch - 26 September 2015

IEEE Transactions on Communications
Issue - September 2015

Paper I

Paper: **Energy-Efficient Subcarrier Assignment and Power Allocation in OFDMA Systems With Max-Min Fairness Guarantees**

-Y. Li, M. Sheng, C. W. Tan, Y. Zhang, Y. Sun, X. Wang, Y. Shi, J. Li

Aim:

- Guarantee individual link fairness: max-min energy efficiency-optimal problem (MEP).
- Maximize the energy efficiency subject to **rate requirements**, **transmit power**, **subcarrier assignment** constraints.

Setup:

- Single cell uplink OFDMA, K active users, N subcarriers.
- Define $\mathbf{P} = (P_{k,n})$, $P_{k,n}$: Tx power of link k on subcarrier n.
- Tx rate, $r_{k,n} = \log_2\left(1 + \frac{P_{k,n}|h_{k,n}|^2}{N_0 B/N}\right)$.
- Total Tx rate on link k, $R_k(\boldsymbol{\rho}, \mathbf{P}) = \sum_{n=1}^{N} \rho_{k,n} r_{k,n}$; $\rho_{k,n}$: Indicator variable.
- Total Tx power on link k, $P_k(\boldsymbol{\rho}, \mathbf{P}) = \sum_{n=1}^{N} \rho_{k,n} P_{k,n}$.
- $R_{\mathrm{tot}}(\boldsymbol{\rho}, \mathbf{P}) = \sum_{k=1}^{K} R_k(\boldsymbol{\rho}, \mathbf{P})$, $P_{\mathrm{tot}}(\boldsymbol{\rho}, \mathbf{P}) = \sum_{k=1}^{K} P_k(\boldsymbol{\rho}, \mathbf{P})$.
- Energy efficiency: $\eta_k^{\mathrm{EE}} = R_k(\boldsymbol{\rho}, \mathbf{P})/P_k(\boldsymbol{\rho}, \mathbf{P})$, and $\eta^{\mathrm{EE}} = R_{\mathrm{tot}}(\boldsymbol{\rho}, \mathbf{P})/P_{\mathrm{tot}}(\boldsymbol{\rho}, \mathbf{P})$.

Energy-Efficient Subcarrier Assignment and Power Allocation... (Li et al.)

Problem formulation:

$$\max_{\boldsymbol{\rho},\mathbf{P}} \min_{k} \quad \eta_k^{\mathrm{EE}}$$

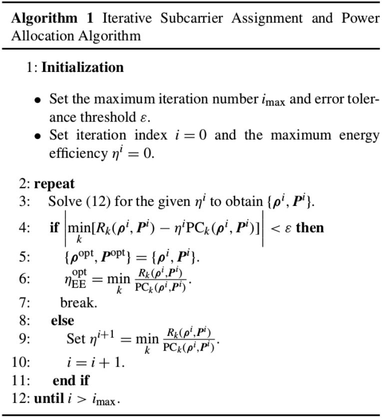
$$\mathrm{C1}: \sum_{n=1}^{N} \rho_{k,n} r_{k,n} \geq R_{\mathrm{req}}, \forall k$$

$$\mathrm{C2}: \sum_{k=1}^{K} \rho_{k,n} r_{k,n} \leq 1, \forall n$$

$$\mathrm{C3}: \sum_{n=1}^{N} \rho_{k,n} P_{k,n} \leq P_{\mathrm{k}}^{\max}, \forall k$$

$$\mathrm{C4}: P_{k,n} \geq 0, \forall k, n$$

$$\mathrm{C5}: \rho_{k,n} \in \{0, 1\}, \forall k, n$$



Algorithm 1 Iterative Subcarrier Assignment and Power Allocation Algorithm

```
Initialization
    • Set the maximum iteration number $i_{\max}$ and error tolerance threshold $\varepsilon$.
    • Set iteration index $i = 0$ and the maximum energy efficiency $\eta^i = 0$.
repeat
    Solve (12) for the given $\eta^i$ to obtain $\{\boldsymbol{\rho}^i, \boldsymbol{P}^i\}$.
    if $\left|\min_k [R_k(\boldsymbol{\rho}^i, \boldsymbol{P}^i) - \eta^i \mathrm{PC}_k(\boldsymbol{\rho}^i, \boldsymbol{P}^i)]\right| < \varepsilon$ then
        $\{\boldsymbol{\rho}^{\mathrm{opt}}, \boldsymbol{P}^{\mathrm{opt}}\} = \{\boldsymbol{\rho}^i, \boldsymbol{P}^i\}$.
        $\eta_{\mathrm{EE}}^{\mathrm{opt}} = \min_k \frac{R_k(\boldsymbol{\rho}^i, \boldsymbol{P}^i)}{\mathrm{PC}_k(\boldsymbol{\rho}^i, \boldsymbol{P}^i)}$.
        break.
    else
        Set $\eta^{i+1} = \min_k \frac{R_k(\boldsymbol{\rho}^i, \boldsymbol{P}^i)}{\mathrm{PC}_k(\boldsymbol{\rho}^i, \boldsymbol{P}^i)}$.
        $i = i + 1$.
    end if
until $i > i_{\max}$.
```

- Mixed-integer non-linear programming - hard to solve, non-convex even after relaxing $\rho_{k,n} \in [0, 1]$.
- **Replace objective by**: $\max_{\boldsymbol{\rho},\mathbf{P}} \min_k \quad R_k(\boldsymbol{\rho}, \mathbf{P}) - \eta P_k(\boldsymbol{\rho}, \mathbf{P})$.

Energy-Efficient Subcarrier Assignment and Power Allocation... (Li et al.)

- Objective non-smooth.
- Introduce new variable φ, replace objective by: $\max_{\boldsymbol{\rho},\mathbf{P},\varphi} \varphi$.
- **Add new constraint:** $\mathrm{C6}: R_k(\boldsymbol{\rho},\mathbf{P}) - \eta P_k(\boldsymbol{\rho},\mathbf{P}) \geq \varphi$.

- Apply Lagrangian dual decomposition on the new problem: $L(\boldsymbol{\rho},\mathbf{P},\varphi,\boldsymbol{\beta},\boldsymbol{\mu},\boldsymbol{\nu},\boldsymbol{\gamma})$.

Iterate:

- Solve for optimal $P^*_{k,n}$ and $\rho^*_{k,n}$ by differentiating the Lagrangian.
- Update Lagrange multipliers using subgradient projection.

- Separate subcarrier assignment and power allocation problems to devise simpler algorithms.

Paper II

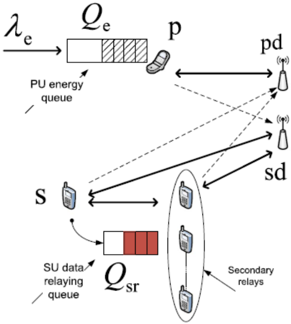
Paper: **A Sparsity-Aware Cooperative Protocol for Cognitive Radio Networks With Energy-Harvesting Primary User**.

-A. El Shafie, N. Al-Dhahir, and R. Hamila.

Aim:

- Design a dynamic relaying cooperative protocol for a CR setting - SUs coexist with energy-harvesting PUs.
- CS-aided protocol where the SUs also act as dynamic relay nodes.
- Design of a beamformer so that relay nodes can transmit without interference to PU destination.

Setup:



- Each channel has 1 PU and 1 SU, *N* SUs act as relaying nodes.
- h_{n_1,n_2}: channel coefficient from node n_1 to n_2.

Proposed Protocol:

- SU source & SU relays sense the channel for PU activity.
- SU source transmits packets probabilistically (prob. 1 if direct link is not in outage, and prob. ω if direct link is in outage and relay buffer has $0 < m < D$ packets).
- If #decoding relays $< \beta$, packet is erroneously decoded at secondary destination, and will be retransmitted.
- When s-sd link is in outage, and source transmits, each relay sends 1 bit to indicate whether it is a decoding relay or not.
- If PU is active, secondary source is idle. SU relays forward the packets using relevant BF weights.
- Feedback: destination sends a feedback to indicate the status of decodability.

CS Principles

- Applied when the relays send their states of being decoding relays or not.
- Instead of sending N orthogonal signals to source to describe state of each relay, CS techniques used to reduce the #samples.
- Received signal $\mathbf{r}_j$, $j \in \{\mathrm{s}, \mathrm{sd}\}$:

  $$\mathbf{r}_j = \mathbf{A}\mathbf{H}_j^H \mathbf{x} + \mathbf{Z}_j,$$

  $\mathbf{A} : [\mathbf{a}_1 \ \mathbf{a}_2 \ \cdots \mathbf{a}_N]$, N: Total number of relays.
- Need only $h_{k,j} x_k$ without estimating $h_{k,j}$; # Non-zero entries in $\mathbf{H}_j^H \mathbf{x} = K$.
- Random matrix $\mathbf{A}$ is known to SU source and destination.

A Sparsity-Aware Cooperative Protocol for Cognitive Radio Networks... (Shafie et al.)

Beamformer design

- Weights $\mathbf{g}_a \in \mathbb{C}^K$: active PU
- **Active PU**: Relays transmit one of the packets. Optimal weight vector $\mathbf{g}_a$:

$$\max_{\mathbf{g}_a} |\mathbf{g}_a^H \mathbf{h}_{\mathrm{sd}}^{(\Omega)}|^2, \quad \mathrm{s.t.} \quad |\mathbf{g}_a^H \mathbf{h}_{\mathrm{pd}}^{(\Omega)}| = 0,$$

$\mathbf{h}_{\mathrm{sd}}^{(\Omega)} = [h_{1,\mathrm{sd}}, \ldots, h_{\mathrm{K},\mathrm{sd}}]$, $\mathbf{h}_{\mathrm{pd}}^{(\Omega)} = [h_{1,\mathrm{pd}}, \ldots, h_{\mathrm{K},\mathrm{pd}}]$, Ω : Set of chosen relays.

Performance Analysis

- Outage analysis, queuing analysis, PU throughput analysis, SU throughput maximization...

Paper III

Paper: **Wideband Millimeter-Wave Propagation Measurements and Channel Models for Future Wireless Communication System Design**.

-T. S. Rappaport, G. R. MacCartney, Jr., M. K. Samimi, S. Sun.

Aim:

- Experimental measurements & empirically-based propagation channel models for 28, 38, 60, 73 GHz mmWave bands.
- Analysis of more than $15,000$ power delay profiles in urban macrocells and microcells.

Specs:

- Wideband sliding correlator - ns-scale temporal resolution.
- Measurements for each frequency band - numerous large-scale path loss meas. for multiple AOA & AOD orientations of Tx and Rx.

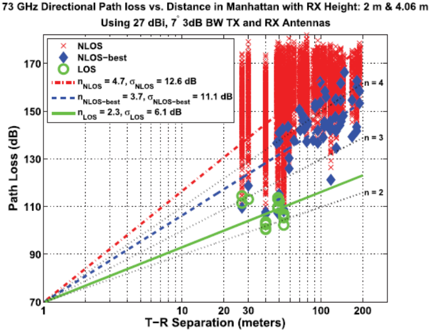
Wideband Millimeter-Wave Propagation Measurements... (Rappaport et al.)

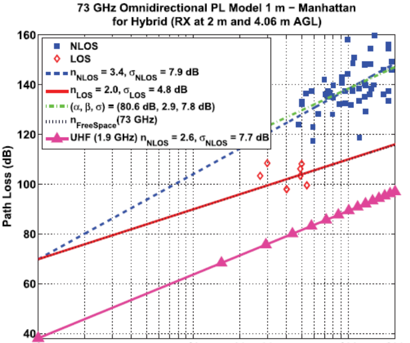
Directional Path Loss Models

$$\mathrm{PL}(d)[\mathrm{dB}] = \mathrm{PL}(d_0) + 10\bar{n}\log_{10}\left(\frac{d}{d_0}\right) + X_0, d \geq d_0, \ (d_0 = 1). \tag{1}$$

Omnidirectional Path Loss Models

$$\mathrm{PL}_{i,j}[\mathrm{dB}] = \mathrm{Pt}_{i,j} - 10\log_{10}\left[\sum_z \sum_y \sum_x \sum_w \mathrm{Pr}_{i,j}(\theta_{r_w}, \phi_{r_x}, \theta_{t_y}, \phi_{t_z})[\mathrm{mW}]\right] \tag{2}$$



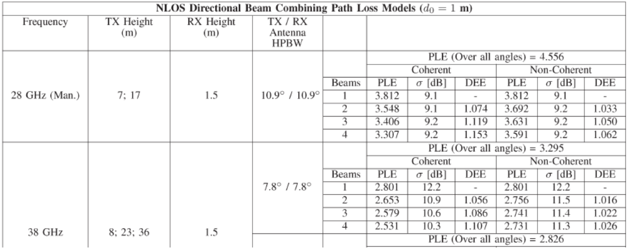


Wideband Millimeter-Wave Propagation Measurements... (Rappaport et al.)

Beam Combining

- ↓ in PLEs for both coherent and non-coherent beam combining- ↑ coverage distance.

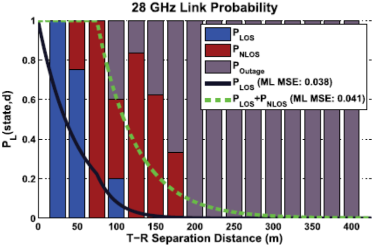
$$P_{\text{coh}} = \left(\sum_{i=1}^{N} \sqrt{P_i}\right)^2$$
$$P_{\text{non-coh}} = \sum_{i=1}^{N} P_i$$
$$d_{\text{beam}} = [d_{1-\text{beam}}]^{\text{DEE}}$$



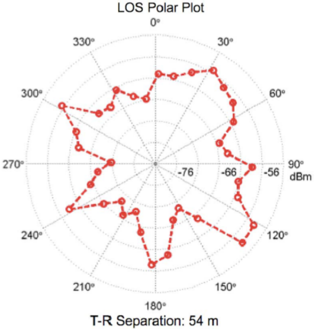
<table>
<tr><th colspan="11">NLOS Directional Beam Combining Path Loss Models ($d_0 = 1$ m)</th></tr>
<tr><th>Frequency</th><th>TX Height (m)</th><th>RX Height (m)</th><th>TX / RX Antenna HPBW</th><th></th><th colspan="6"></th></tr>
<tr><td rowspan="7">28 GHz (Man.)</td><td rowspan="7">7; 17</td><td rowspan="7">1.5</td><td rowspan="7">10.9° / 10.9°</td><td></td><td colspan="6">PLE (Over all angles) = 4.556</td></tr>
<tr><td></td><td colspan="3">Coherent</td><td colspan="3">Non-Coherent</td></tr>
<tr><td>Beams</td><td>PLE</td><td>σ [dB]</td><td>DEE</td><td>PLE</td><td>σ [dB]</td><td>DEE</td></tr>
<tr><td>1</td><td>3.812</td><td>9.1</td><td>-</td><td>3.812</td><td>9.1</td><td>-</td></tr>
<tr><td>2</td><td>3.548</td><td>9.1</td><td>1.074</td><td>3.692</td><td>9.2</td><td>1.033</td></tr>
<tr><td>3</td><td>3.406</td><td>9.2</td><td>1.119</td><td>3.631</td><td>9.2</td><td>1.050</td></tr>
<tr><td>4</td><td>3.307</td><td>9.2</td><td>1.153</td><td>3.591</td><td>9.2</td><td>1.062</td></tr>
<tr><td rowspan="8">38 GHz</td><td rowspan="8">8; 23; 36</td><td rowspan="8">1.5</td><td rowspan="7">7.8° / 7.8°</td><td></td><td colspan="6">PLE (Over all angles) = 3.295</td></tr>
<tr><td></td><td colspan="3">Coherent</td><td colspan="3">Non-Coherent</td></tr>
<tr><td>Beams</td><td>PLE</td><td>σ [dB]</td><td>DEE</td><td>PLE</td><td>σ [dB]</td><td>DEE</td></tr>
<tr><td>1</td><td>2.801</td><td>12.2</td><td>-</td><td>2.801</td><td>12.2</td><td>-</td></tr>
<tr><td>2</td><td>2.653</td><td>10.9</td><td>1.056</td><td>2.756</td><td>11.5</td><td>1.016</td></tr>
<tr><td>3</td><td>2.579</td><td>10.6</td><td>1.086</td><td>2.741</td><td>11.4</td><td>1.022</td></tr>
<tr><td>4</td><td>2.531</td><td>10.3</td><td>1.107</td><td>2.731</td><td>11.3</td><td>1.026</td></tr>
<tr><td></td><td></td><td colspan="6">PLE (Over all angles) = 2.826</td></tr>
</table>

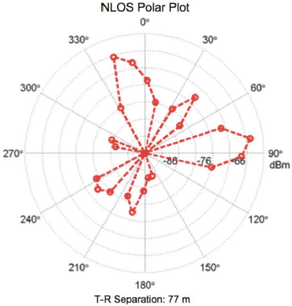
Outage Studies

$$p_{\text{outage}}(d) = \max(0, 1 - e^{-a_{\text{out}} d + b_{\text{out}}}),$$
$$p_{\text{LOS}}(d) = (1 - p_{\text{outage}}(d)) e^{-a_{\text{out}} d},$$
$$p_{\text{NLOS}}(d) = 1 - p_{\text{outage}}(d) - p_{\text{LOS}}(d).$$



Spatial Properties





- RMSE delay spreads, multipath effects, peer-to-peer and vehicular channel responses...

Paper IV

Paper: **Antenna Grouping Based Feedback Compression for FDD-Based Massive MIMO Systems**.

-B. Lee, J. Choi, J.-Y. Seol, D. J. Love, B. Shim.

Aim:

- Reduce the CSI feedback overhead from user-terminal to base station.
- Antenna grouping- to map multiple correlated antenna elements into one representative value.
- Lower quantization error than conventional vector quantization (channel-statistic based codeword).

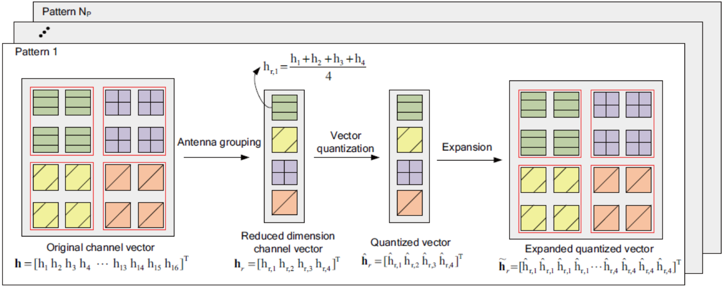
Prelims:

- Multiuser multiple-input, single-output downlink channel
- Assume spatially and temporally correlated block-fading channels - channel vector $\mathbf{h}_k$ follows first-order Gauss-Markov model.
- Data model: $\mathbf{y}[n] = \mathbf{H}\mathbf{x}[n] + \mathbf{z}[n]$; $\mathbf{y}[n] \in \mathbb{C}^{K \times 1}$, $\mathbf{H}[n] \in \mathbb{C}^{K \times N_t}$
- To feedback CSI, user quantizes $\mathbf{h}_k$, chooses codeword from pre-defined codebook set.

Antenna Grouping Based Feedback Compression... (Lee et al.)

Antenna Grouping Based Feedback Reduction

- Reduce dimension of $\mathbf{h}_k$ from N_t to N_g - grouping multiple correlated antennas.
- Feedback: header- group pattern, payload- index of quantized $\mathbf{h}_k$.
- Group pattern generation: AGB is sensitive to choice of antenna pattern.
- Either group antennas spatially, or use Grassmannian subspace packing. [D.J. Love et al. "Grassmannian beamforming..", 2003].
- Grassmannian approach has substantial gain over randomly selecting patterns.



Some other papers

- Quickest Wideband Spectrum Sensing Over Correlated Channels- A. Tajer and J. Heydari.
- Energy-Efficient Resource Management in OFDM-Based Cognitive Radio Networks Under Channel Uncertaint - S. Wang, W. Shi, and C. Wang.
- Secrecy Performance Analysis for SIMO Simultaneous Wireless Information and Power Transfer Systems - G. Pan, C. Tang, T. Li, and Y. Chen.